

NAME P/N QTY	CRIT	FAILURE MODE & CAUSES	FAILURE EFFECT	RATIONALE FOR ACCEPTANCE

RESTRAINT 4000, ITEM 106 (1) LEFT (1) RIGHT ----- 0106-88936-11/12 (2)	2/1R	Loss of primary axial restraint/gimba l support. Defective Material, Abraded thread or webbing. Loss of gimbal swivel screw. Defective gimbal swivel.	END ITEM: Loss of primary axial load restraining capability. GFE INTERFACE: Load will be transferred to secondary restraint/gimba l support. MISSION: None with loss of primary restraint/pivot . Terminate EVA with loss of secondary restraint/ secondary restraint gimbal support.	A. Design - 4000: The glove wrist primary restraints are fabricated from 5/8" wide polyester webbing having a minimum tensile strength of 600 lbs. Front and rear axial restraints are attached to 6.0 ounce dacron fabric reinforcements and 3.0 ounce dacron restraint fabric with bar stitching at each end joined with a double row of stitching formed from size "E" polyester thread. Side axial restraints are attached to the wrist restraint flange seam with size "F" polyester thread. Sewing thread conforming to V-T-285D type II class I is used to fabricate and attach primary webbings and fabric reinforcements. Lock stitch type 301 per FED-STD-751A secures fabric reinforcements and front/rear primary webbings. Zig zag stitch type 304 attaches the side primary webbings. All stitching is terminated on the restraint exterior with a surgeon's knot which is coated with urethane adhesive. Size 16 needles are utilized for stitching to prevent fabric/webbing damage. Front/rear and side axial restraints pulled to destruction during design verification testing exhibited minimum ultimate strengths of 315 lbs./430 lbs. and 502 lbs. respectively, demonstrating factors of safety of 2.3/7.4 and 3.1 against the respective S/AD limit load of 136.2 lbs., 58.2 lbs., and 162 lbs. min.
RESTRAINT PHASE VI, ITEM 106 (1) LEFT (1) RIGHT ----- 0106-812146-01/02 (2)				Abraded thread and webbing are precluded by design as a function of the abrasion protection afforded to the glove restraint by the TMG. Abrasion of the restraint webbing caused by relative motion is reduced by the use of a gimbal swivel to attach the webbings to the gimbal ring. The swivel is coated with a dry film lubricant (Dow Corning 321) to assure free movement.
----- 0106-812146-03/04 (2)			CREW/VEHICLE: None with single failure. Loss of crewman with failure of secondary restraint/ secondary restraint gimbal support.	Loss of a gimbal swivel screw is precluded by adherence to standard engineering torque requirements for screw installation and the use of thread locking adhesive. The gimbal swivel is fabricated from 17-4 PH stainless steel heat treated to H1050. Components are subjected to radiographic (casting) and magnetic particle (machined) to preclude defective material/parts. Tensile testing of the wrist gimbal swivel demonstrated a minimum safety factor of 3.1 without yielding against a S/AD limit load of 162 lbs.
			TIME TO EFFECT /ACTIONS: Minutes.	Phase VI: The glove wrist design carries the axial loads through the use of a lower primary webbing, a middle primary webbing, an upper primary fabric sheath and two gimbal rings. This mode addresses the lower and middle primary webbings which have redundant secondary webbings.
			TIME AVAILABLE: Days.	The lower primary is fabricated from a 7/8" wide Spectra webbing, one gimbal swivel, Kevlar thread and two stainless steel brackets. The webbing is routed through the gimbal swivel and overlapped back on itself. The webbing is joined with a backtack using 200 denier Kevlar thread. The Kevlar stitching is covered with a Teflon fabric abrasion layer. The end of the webbing opposite the swivel forms a loop through which the lower bracket is passed. The upper bracket then indexes over top the webbing loop centered on the lower bracket. The lower primary webbing has minimum tensile strength of 755 lbs demonstrating a minimum safety factor of 3.5 against the limit load of 214.5 lbs.
			TIME REQUIRED: Hours.	
			REDUNDANCY SCREENS: A-PASS B-N/A	The middle primary is fabricated from a 5/8" wide polyester webbing, two glove gimbal swivels and Kevlar thread. The primary also includes a Teflon abrasion

NAME P/N QTY	CRIT	FAILURE MODE & CAUSES	FAILURE EFFECT	RATIONALE FOR ACCEPTANCE
--------------------	------	-----------------------------	----------------	--------------------------

106FM03

C-PASS

cover. The polyester webbing is routed through the swivels and overlapped in the middle. The webbing is stitched using a bartack. The webbing between the swivels is then covered in Teflon fabric for abrasion resistance. The middle primary webbing has a minimum tensile strength of 490 lbs demonstrating a minimum safety factor of 2.3 against the limit load of 214.5 lbs.

Abraded thread and webbing are precluded by design as a function of the abrasion protection afforded to the glove restraint by the TMG. Abrasion of the restraint webbing caused by relative motion is reduced by the use of a gimbal swivel to attach the webbings to the gimbal ring. The swivel is coated with Nedox to assure free movement.

Loss of a gimbal swivel screw is precluded by adherence to standard engineering torque requirements for screw installation and the use of thread locking adhesive. The gimbal swivel is fabricated from 17-4 PH stainless steel heat treated to H1050. Components are subjected to radiographic (casting) and magnetic particle (machined) to preclude defective material/parts. Tensile testing of the wrist gimbal swivel demonstrated minimum safety factor of 2.0 over ultimate against a limit load of 214.5 lbs.

B. Test -
 Acceptance:
 4000:

The glove primary restraints are subjected to the S/AD limit load of 162 lbs during fabrication of each glove restraint.

Phase VI:

The glove primary restraints are subjected to the S/AD limit loads of 214.5 lbs during fabrication of each glove restraint.

PDA:

Phase VI/4000:

The following tests are conducted at the glove assembly level in accordance with ILC Document 0111-70028 (4000 glove) or 0111-710112 (Phase VI glove):

1. Proof pressure test at 8.0 (+0.2 - 0.0) psig to verify no structural damage.

Certification:

4000:

The glove restraint assembly was successfully subjected to an ultimate pressure of 13.2 psig during SSA certification (Ref. Document 0111-77511). This is 1.5 times the BTA maximum operating pressure based on 8.8 psig.

Recertification to 5.5 psi was by test and analysis (Ref. ILC EM 84-1108).

The glove assembly was successfully tested (manned) during SSA certification to duplicate operational life.

The following usage, reflecting requirements of significance to the 4000 Glove restraints, was documented during certification:

4000:

Primary Axial Restraint

Requirements	S/AD	Actual
-----	-----	-----
Wrist Cycles	28,276	29,484

NAME P/N QTY	CRIT	FAILURE MODE & CAUSES	FAILURE EFFECT	RATIONALE FOR ACCEPTANCE
--------------------	------	-----------------------------	----------------	--------------------------

106FM03

Wrist Rotations	28,216	29,484
Finger Cycles	56,550	56,726
Pressurized Hours	615	615
Pressurized Cycles	376	576
Don/Doff Cycles	192	192

The following usage reflecting requirements of significance to the 4000 Glove restraint was documented during 25 EVA certification. (Ref. EM # 93-1131).

Secondary Axial Restraint Requirements	S/AD	Actual
Wrist Flex/Ex	4186	16120
Wrist Add/Abd	4186	21700
Finger Flex/Ext	8372	56420
Wrist Rotation	4186	25420
Pressure Cycles	32	196

Phase VI:

The glove restraint assembly was successfully tested (manned) during certification testing to duplicate operational usage (Ref. Certification Test Report for the Phase VI Glove, ILC Doc. 0111-712701). The following usage, reflecting requirements of significance to the glove restraint assembly, was documented during certification testing. The S/AD applies 229 hours in certification while the actual indicates 198 hours toward the Phase VI glove restraint in the Hamilton Sundstrand Limited Life Items list (EMU1-19-001).

Requirements	S/AD	Actual
Glove Joint Cycles Flex/Ext (fingers)	45142	39169
Wrist Joint Cycles Add/Abd	17104	14830
Flex/Ext	12646	10830
Rotations	20112	17393
Pressurized Hours	229	198
Pressurized Cycle @ 4.3 psig	97	99
5.3 psig	37	63
6.6 psig	16	18
Don/Doff Cycles	49	49

The glove assembly was successfully subjected to an ultimate pressure of 13.2 psig during Certification Testing (Ref. ILC doc 0111-712701). This is 1.5 times the maximum BTA operating pressure based on 8.8 psig.

C. Inspection -
 4000/Phase VI:

Components and material manufactured to ILC requirements at an approved supplier are documented from procurement through shipping by the supplier. ILC incoming receiving inspection verifies that the materials received are as identified in the procurement documents, that no damage has occurred during shipment and that supplier certifications have been received which provide traceability information.

NAME P/N QTY	CRIT	FAILURE MODE & CAUSES	FAILURE EFFECT	RATIONALE FOR ACCEPTANCE
--------------------	------	-----------------------------	----------------	--------------------------

106FM03

The following MIP's are performed during the glove assembly manufacturing process to assure that the failure causes are precluded from the fabricated item:

4000/Phase VI:

1. Visual inspection of the thread and webbing upon completion of the primary restraint webbing pull test for signs of defective threads and material.
2. Verification of the presence of screws during application of Loctite and torquing of the gimbal swivel screw.
- 3 (4000 only). Verification of the application of lubrication to swivels. During PDA, the glove is visually inspected for structural damage following proof pressure test per ILC Document 0111-70028 (4000 glove) or 011-710112 (Phase VI glove).

D. Failure History -

B-EMU-106-A023 (8/21/90) - Screws which attach gimbal swivel to gimbal ring on 4000 series glove not flush with washer surfaces due to a wider, out-of-specification washer countersink angle which allowed screw heads to extend above washer surfaces. Inspection of washer countersink hole changed to measure the countersink angle with an angle gauge instead of a screw with a 100 degree head.

B-EMU-106-A043 (03/01/99) -

Remote Powered Heated Glove Assembly (RPHGA) right glove outboard gimbal swivel did not operate freely. Three of four swivels were binding due to severe galling as a result of lubricant depletion. No corrective action required. Pre-flight testing per FEMU-R-001 provide for detection of swivel binding, and procedure dictates inspection after each 56 hours of MPT (manned pressurized time). A large margin exists between the maximum time which can be accumulated between inspections (63 hours MPT) and the demonstrated worst case interval (350 hours MPT). Note: This failure does not apply to Phase VI Gloves.

B-EMU-106-A045 (6/7/99)-

Gimbal swivel binding. Minor galling on inboard, outboard, and palm side gimbals. Since eventual galling is inherent in the design of the 4000 series glove, several screens, including the FEMU-R-001 document, exist to detect galling before it becomes serious. At NASA's request, future visual observations of gimbal galling will be documented on Discrepancy Reports. Failure investigations will only be warranted for galling severe enough to fail the existing Functional Operation of Softgoods test. This failure does not apply to Phase VI gloves.

B-EMU-106-A047 (7/14/99) -

Tracked by B-EMU-106-A045

B-EMU-106-A048 (7/14/99) -

Tracked by B-EMU-106-A045

B-EMU-106-A046 (7/14/99) -

Tracked by B-EMU-106-A045

J-EMU-106-A003 (6/24/99) -

Tracked by B-EMU-106-A045

NAME P/N QTY	CRIT	FAILURE MODE & CAUSES	FAILURE EFFECT	RATIONALE FOR ACCEPTANCE
		106FM03		<p>B-EMU-106-A050 (8/23/99) - Tracked by B-EMU-106-A045</p> <p>B-EMU-106-A051 (8/24/99) - Tracked by B-EMU-106-A045</p> <p>B-EMU-106-A052 (8/24/99) - Tracked by B-EMU-106-A045</p> <p>Phase VI: B-EMU-106-T002 (2/29/00) - Primary restraint found frayed during glove bladder change-out. Caused by improper installation. Restraint bracket pinched PAR webbing as bracket was torqued during installation of restraint/bladder to glove disconnect. ILC ECO's 002 -117, 118, & 119 update EMU Maint. Manuals to include warnings at installation.</p> <p>J-EMU-106-A009 (5/19/01) - During STS-104 pre-flight processing, it was noted that the glove thumb side slotted gimbal pivot had excessive gap between washer and gimbal interface. Glove gimbal washer mis-oriented at assembly. Work instructions revised to ensure correct assembly.</p> <p>E. Ground Turnaround - 4000/Phase VI: During ground turnaround, in accordance with FEMU-R-001, the glove assembly is visually inspected (pressurized and unpressurized) with TMGs removed for; structural integrity, material damage or degradation and loose or missing screws. Also, during structural and leakage tests the proper operation of the gimbal swivel is verified. Every 56 hours (4000) of manned pressurized time the glove restraint is subjected to a complete visual inspection which includes visual inspection of the thread and webbing during which the gimbal swivels are inspected, lubricated and Loctite and screw torque are verified.</p> <p>F. Operational Use - 4000/Phase VI: 1. Crew Response - Pre/post-EVA : If detected by glove elongation, troubleshoot problem. If no success, use spare gloves if available. Otherwise, no go for EVA. EVA : If detected by glove elongation, terminate EVA.</p> <p>2. Training - No training specifically covers this failure mode.</p> <p>3. Operational Considerations - Generic EVA Checklist, JSC-48023, procedures Section 3 (EMU Checkout) and 4 (EVA prep) verify hardware integrity and systems operational status prior to EVA. Real Time Data System allows ground monitoring of EMU systems.</p>

EXTRAVEHICULAR MOBILITY UNIT
SYSTEMS SAFETY REVIEW PANEL REVIEW
FOR THE
I-106 GLOVE ASSEMBLY
CRITICAL ITEM LIST (CIL)

EMU CONTRACT NO. NAS 9-97150

Prepared by: *J. Amman*
HS - Project Engineering

Approved by: *RP* 22mar/02
NASA - SSA/SSM

M. Snyder
HS - Reliability

NA Blaw 5/23/02
NASA - EME/SSM

R. Mumford 4/24/02
HS - Engineering Manager

Cherlyn 6/3/02
NASA - IS/MA

Mike 6/3/02
NASA - MOD

John 6/5/02
NASA - Crew

Bob 6/3/02
NASA - Program Manager